DARPA SIMPLEX PROPOSERS' DAY

SEPTEMBER 9, 2014 • ECC

Time	Subject
8:00 – 9:00 AM	Registration
9:00 – 9:30 AM	DSO Overview – Dr. Stefanie Tompkins, *DARPA DSO Director*
9:30 – 9:45 AM	Contract Management Office Briefing – Mr. Michael Mutty, *DARPA CMO*
9:45 – 10:15 AM	SIMPLEX Overview – Dr. Reza Ghanadan, *DARPA DSO*
10:15 – 10:30 AM	Break
10:30 – 11:30 PM	Participant Presentations (2 min. each):
11:30 – 1:30 PM	Working Lunch: 1) Discussion: Teaming – Rules of Engagement 2) Attendees may submit questions on cards for Q&A session
1:30 – 2:45 PM	Participant Presentations Continued (2 min. each):
2:45 – 3:00 PM	Break
3:00 – 4:00 PM	Participant Discussions / Informal Sidebars
4:00 – 4:30 PM	Answers to submitted questions

Defense Sciences Office

Dr. Stefanie Tompkins

September 9, 2014

DARPA Technical Offices

BTO

Biology, Technology & Complexity

- **Restore and Maintain Warfighter Abilities**
- **Harness Biological Systems**
- **Apply Biological Complexity at Scale**

DSO

Discover, Model, Design & Build

- **Physical Sciences**
- **Mathematics**
- **Transformative Materials**
- **Supervised Autonomy**
- **Novel Sensing and Detection**
- **Complexity**

I2O

Information, Innovation & Cyber

- **Cyber**
- **Data Analysis at Massive Scales**
- **ISR Exploitation**

MTO

Electronics, Photonics & MEMS

- **Biological Platforms**
- **Computing**
- **Electronic Warfare**
- **Manufacturing**
- **Novel Concepts**
- **Photonics**
- **Positioning, Navigation and Timing**
- **Thermal Management**

STO

Networks, Cost Leverage & Adaptability

- **Battle Mgmt, Command & Control**
- **Comms & Networks**
- **ISR**
- **Electronic Warfare**
- **Positioning, Navigation and Timing**

TTO

Weapons, Platforms & Space

- **Air Systems**
- **Ground Systems**
- **Marine Systems**
- **Space Systems**

Who we are:

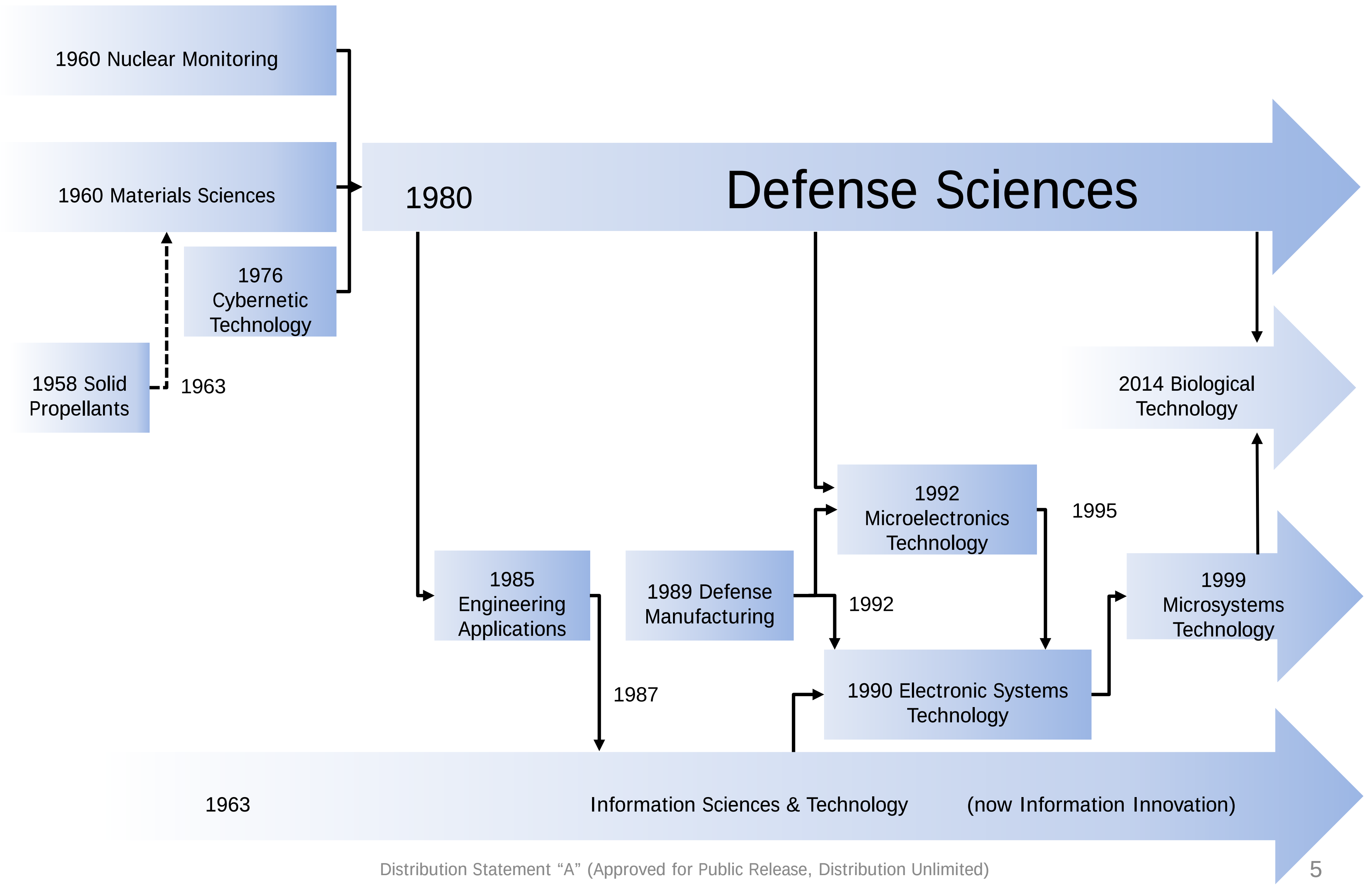
- A collaborative team of diverse, opportunistic technology entrepreneurs
- "DARPA's DARPA" – office that creates DoD opportunity from fundamental scientific discovery
- Informed, but not constrained, by current trends and conflicts

What we do:

- Invest in multiple, often disparate, scientific disciplines
- Reshape existing fields or create entirely new disciplines (sometimes when the payoff to DoD may not be fully understood)
- Harvest and accelerate the development of promising breakthroughs to create enabling technologies for broad impact against national security challenges

The Nation's first line of defense against <u>scientific</u> surprise

DSO Office History



National Security Challenges

- Diverse threats: Expanding military missions in widely varying environments demand a level of customization that we do not have
  - Can we counter the diversity of national security threats by rapidly accelerating scientific discovery and innovation?
- Speed of change: Globally available technology is moving more quickly than we typically react
  - Can we speed the creation of new capabilities, to respond or adapt to unpredictable threats? Can we remove technology barriers to rapid or low volume acquisition?
- Complex systems: Unsustainable cost of military systems limits adaptability, choice, and incorporation of new technology
  - Can we harness complexity in the systems we build? Can we quantify and manage uncertainty and risk for robust, less costly systems?
- Erosion of boundaries: Weapons of terror and potential proliferation of WMD technology affect both war and peace, home and abroad
  - Can reliable and timely detection and management of CBRNE materials and devices address WMD threats arising from the erosion of boundaries?

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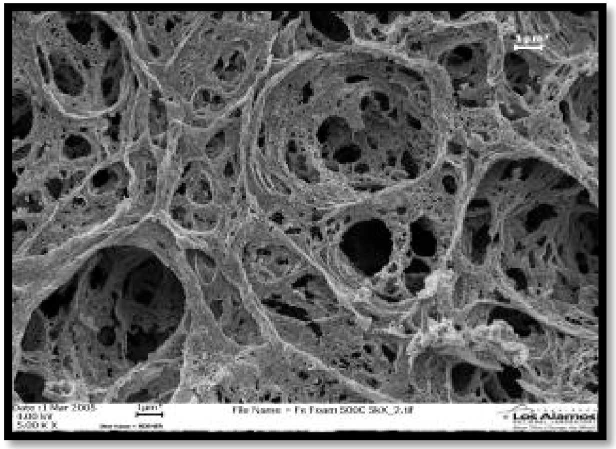
Bubbling Technology Opportunities

???

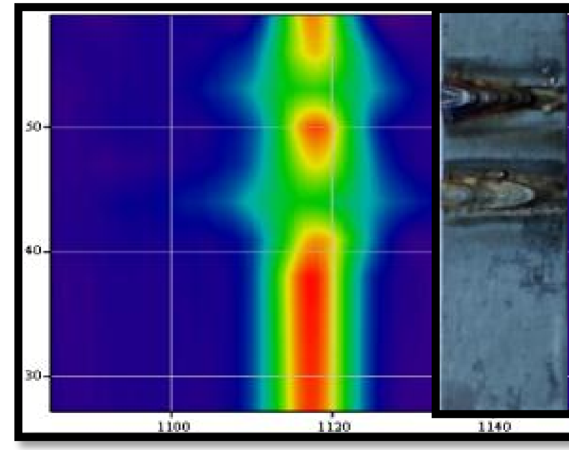
(Tell us what you think they are)

Topic Areas



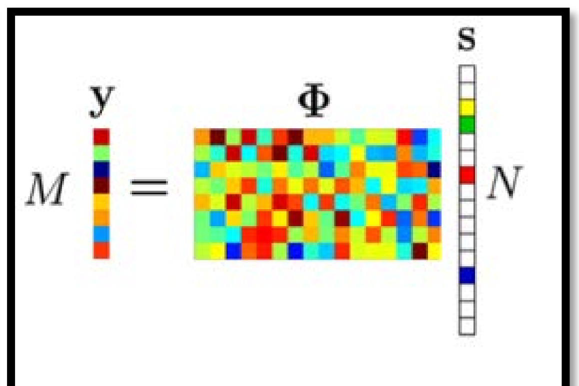
Transformative Materials
Decoupling and control of countervailing material properties; design and fabrication of new materials across multiple length scales

Supervised Autonomy
Development of theory, tools, and components to enable extended autonomous activity in unstructured, infrastructure-poor environments



Novel Sensing and Detection
New approaches to sensing and detecting CBRNE materials and devices

Physical Sciences
Exploration of scientific breakthroughs and boundaries that enable unique capabilities for national security



Mathematics
Development of advanced mathematics and modeling tools

Complexity
Exploration of the science of complexity, and its application to new engineering paradigms

We look forward to your ideas.

BROAD AGENCY ANNOUNCEMENT PROCESS

SIMPLEX

MICHAEL MUTTY
CONTRACTING OFFICER
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

DARPA BAA-14-59

SEPTEMBER 9, 2014

BAA SPECIFICS

BAA and any amendments posted in FEDBIZOPPS And GRANTS.GOV

- BAA covers all info needed to propose
- TIME PERIOD –

  Abstracts

  Full Proposals

- Instructions are detailed in the BAA (**Follow closely**)
- **Following the proposal instructions assists the evaluation team to clearly understand what is being proposed and supports a timely negotiation.**
- **ALL** questions to SIMPLEX@darpa.mil

BAA Background

- Federal Acquisition Regulation (FAR) Part 35
- http://farsite.hill.af.mil
- “A general announcement of an agency’s research interest including criteria for selecting proposals of all offerors capable of satisfying the Government’s needs.”
- For the acquisition of basic and applied research not related to the development of a specific system or hardware procurement.

BAA Background (cont.)

- Used when proposals with varying technical and scientific approaches can be expected
- Proposals need not be evaluated against one another since they are not submitted in accordance with a common work statement.
- Primary basis for selecting proposals shall be technical, importance to agency programs, and fund availability.
- Cost realism shall also be considered

Communications

Communications

- **ALL** questions to SIMPLEX@darpa.mil
- After Receipt of Proposals – Government (PM/PCO) may communicate with proposers to understand the meaning of some aspect of the proposal that is not clear or to obtain confirmation or substantiation of a proposed approach, solution, or cost estimate
- Informal feedback may be provided once selection(s) are made

Applicant Eligibility

- All interested/qualified sources may respond
- International participants/resources may participate to the extent authorized by applicable Security Regulations, Export Laws, etc.
- Small Business Participation Encouraged, Teaming Not Required

- Government agencies/labs, FFRDCs cannot propose to this BAA in any capacity, **UNLESS** they can clearly demonstrate the work is not otherwise available from the private sector AND they also provide written documentation citing the specific statutory authority (as well as, where relevant, contractual authority) establishing their eligibility to propose to government solicitations

Award Type

<u>Award Instrument</u>

- Procurement Contract, Cooperative Agreement, or Other Transactions
  - http://farsite.hill.af.mil/ (FAR Contracts)
  - http://www.darpa.mil/Opportunities/Contract_Management/Grants_and_Cooperative_Agreements.aspx (Grants, Cooperative Agreements)
- In all cases the Contracting Officer shall have sole discretion to select award type instrument

Rights to Technical Data and Computer Software

- Assert rights to all technical data & computer software generated, developed, and/or delivered to which the Government will receive less than Unlimited Rights Assertions apply to Prime and Subs
- Justify “Basis of Assertion”
- Use defined “Basis of Assertion” and “Rights Category”
- Assessed during evaluation under the “Potential to Accomplish Technology Transition” Evaluation Factor

Simplifying Complexity in Scientific Discovery (SIMPLEX)

Dr. Reza Ghanadan

Proposers Day Briefing

September 9, 2014

Disclaimer

- This briefing is solely for informational purposes.
- Nothing said at Proposers Day changes the requirements set forth in the BAA.
- The BAA supersedes anything presented or said by DARPA at the Proposers Day.
- Examples in this briefing (e.g. of representations or domain use cases) are chosen for ease of illustration only and do not constitute endorsement of any particular approach.

Program Vision – Maximize the Value of Scientific Data

With more scientific data than ever before,
we need proper tools to turn it into big discoveries.

Complex Problem

- Understanding, representing, and making discoveries in complex science is difficult.
  - Many interacting components.
  - Heterogeneous.
  - Multi-scale (spatial, temporal, causal).
- State of practice: Divide-and-conquer.
  - Leads to lots of fragmented underutilized scientific data.
  - Hard to represent and leverage in a broader context.

SIMPLEX

- Provide discovery, analysis, and hypothesis generation for complex science.
- Unified mathematical representations to encode knowledge in a computable form.
- Encode knowledge (prior-knowledge) to form context.
- Process and analyze observation data using prior-knowledge for context aware analysis.

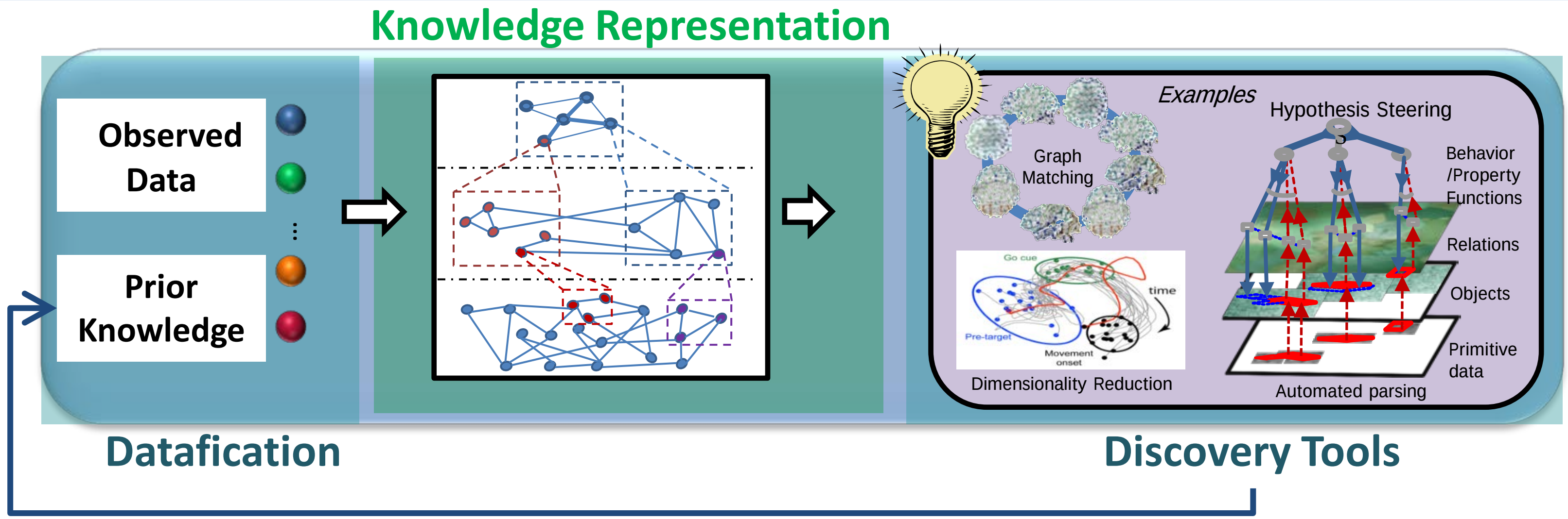
Deliverables

- Mathematical theories, models & methods.
- Computation platform with toolbox & algorithms.
- Demonstration in scientific and engineering use cases.

SIMPLEX Scope and Challenges

Program Scope

- Allow encoding of heterogeneous, quantitative and qualitative domain knowledge into a computational representation, and creation of analytic methods to exploit the representation.
- Use data and the knowledge framework to automatically provide hypothesis generation and steering for complex phenomena and context-aware analysis.
- Promote the joint analysis of related but previously uncoupled data types and sources.



Technical Areas

TA 1: Knowledge Representation

TA 2: Datafication and Discovery Tools

TA1: Mathematical Representation

Knowledge Representation

i. Encodes quantitative and qualitative knowledge, allowing context aware reasoning and computation.
ii. Includes and relates multiple heterogeneous data types and sources.
iii. Allows analytic overlays for reasoning, inference, and hypothesis generation.
iv. Expresses functional relationships between entities in a complex and multi-scale system.
v. Is domain agnostic and extensible to numerous complex domains.
vi. Is agnostic and extensible to a wide range of types of phenomena and systems.

DARPA seeks fundamentally new concepts and encourages approaches to the extent that they allow encoding of complex knowledge beyond what is available today.

TA2: Datafication and Discovery

Datafication: converting phenomena into a computable format for knowledge extraction.

- Example: conversion of brain DTI images into anatomical connectivity networks.
- It may include a data modeling language to develop automated and standard tools.

Datafication efforts should address the following:

- Domain-appropriate data and knowledge format applicable to the majority of domain data.
- Registration and statistical reference tools to combine heterogeneous data and knowledge into a common operating picture.

Discovery: tools, models, and methods for computation/analysis yielding novel insights into the use case.

- Tools that can process on Knowledge Representation.
- TA2 portions of the proposal should describe the discovery tools to be developed, how they are novel, and how they will be used to fulfill use case demonstrations.

Discovery efforts should address the following:

- Novel analysis libraries capable of interacting with domain agnostic TA1 technologies.
- Joint analysis of multiple types of data substantially dissimilar in nature and at different scales.

TA2: Use Cases

- Use Case: a well defined problem within particular scientific or engineering domain that provides an opportunity for the application of SIMPLEX TA1 technology.
  - Problems must be substantial and not addressable with current tools and research frameworks.
  - Example: understanding a specific neural disorder through interactions among gene expression, neuron firing rates, neuro-anatomy, and behavior.
- Use Case requirements:

A. Substantial and heterogeneous data obtained from two or more significantly different modalities (e.g. light microscopy and electrophysiology, or heterogeneous nodes and edges in wireless communications).

AND/OR

B. Substantial data that span at least two scales for which the spatial and/or temporal dynamics are significantly different, requiring different methods or models (e.g. atomic and mesoscopic spatial scales).

AND

C. Established heterogeneous domain knowledge (quantitative / qualitative models, results, and/or domain principles).

Programmatics

- Three planned phases.
  - Phase I (15 months): Build the foundation and apply.
  - Phase II (12 months): Demonstrate.
  - Phase III (12 months): Optimize.
- Anticipate multiple awards in TA1 and multiple in TA2.
  - TA2 teams must be “domain specific” – one domain, one or more use cases.
  - Proposals can address TA1, TA2, or both.
- Strong interaction across technical areas is critical to program success.
  - Work must be validated using the complementary technical area.
  - Integration will be required to address the challenge use cases.

Program Structure

The SIMPLEX program will be divided into three phases:

- Phase I (15 months)
  - TA1 - Create the foundations for a Knowledge Representation.
  - TA1 – Apply Knowledge Representations to use cases.
  - TA2 - Complete and demonstrate datafication.
  - TA2 – Integrate initial Knowledge model.

- Phase II (12 months) – TA1 & TA2
  - Demonstrate Knowledge Representations to use cases.
  - Complete computational platforms.
  - Development of context-aware inference and analysis tools.

- Phase III (12 months) – TA1 & TA2
  - Complete integration of toolset for analysis, modeling, and data-driven hypothesis testing in respective domains.
  - Optimize Knowledge Representation platform for practical use.
  - Complete analysis and discovery library.

Research <u>Not</u> Within the Scope of SIMPLEX

- Hardware development.
- Significant Data Acquisition.
  - Use of existing data preferred.
  - If new collection is necessary, should not be a significant focus.
- Development of text mining methods.
  - Fits within the goal, but there are other ongoing efforts focusing on this.
  - Use of text analytics is fine, but the innovative focus should be elsewhere.

Milestones: Phase I (Foundation)

Technical Area	End of Phase I Milestones (15 months)
TA1 Knowledge Representation	• Completion of the theoretical development of a representation making significant progress per the guidelines of the TA1 goals. • Implementation of baseline algorithms for context-aware reasoning and inference using the representation. • Development of a computational platform, including objectives described in the TA1 description.
TA2 Datafication and Discovery	• Completion of the datafication techniques. • Completion of research and design into domain-specific analysis tools. • Demonstration of data ingestion and registration (compatible with at least one TA1 representation) for at least two modalities or scales. • Completion of encoding knowledge pertinent to the use case into a format compatible with at least one TA1 representation.

Milestones: Phase II (Domain Adaptation)

Technical Area	End of Phase II Milestones (27 months)
TA1 Knowledge Representation	• Theoretical and practical adjustments to the representation allowing scalable implementation. • Development of compact representation to accommodate multi-scale data. • Implementation of prototype platform.. • Demonstration of capabilities and objectives described in the TA1 description, in at least two TA2 domains, at least one of which must come from a different SIMPLEX performer.
TA2 Datafication and Discovery	• Completion of statistical multi-modal (scale) referencing if applicable. • Completion of functional inference capabilities. • Integration of domain-specific computational models iacross modalities and scales. • Instantiation of first-generation analysis tools. • Successful integration and knowledge contextualization leveraging TA1 Knowledge Representations.

Milestones: Phase III (Optimization and Context-aware analysis)

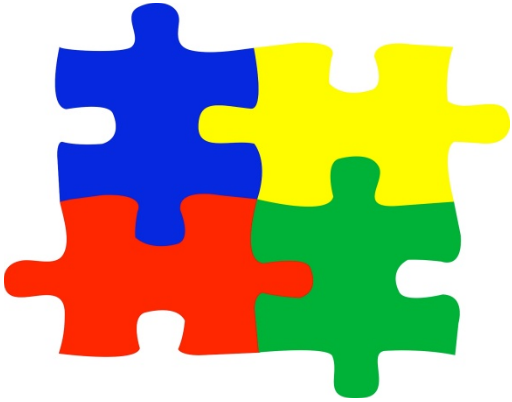
Technical Area	End of Phase III Milestones (39 months)
TA1 Knowledge Representation	• Completion of mathematical tools for hypothesis generation and testing and model validation. • Instantiation of context-aware algorithms capable of running in real-time. • Optimized recall and compact representation for improved performance. • Demonstration on multiple TA2 domains of an integrated system that ingests and registers data and knowledge, allows query and recall, hypothesis generation and steering, and validated analysis.
TA2 Datafication and Discovery	• Completion of toolset for analysis, modeling, and data-driven hypothesis testing in respective domains. • Successful integration with TA1 technology and end of program demonstrations for integrated systems.

Third Party Validation, Workshops and Summer Sessions

- Performers will interact with an independent team of subject matter experts to test and validate SIMPLEX developments.

- To promote early dissemination and collaboration, performers will host local workshops on their methods throughout the program.

- Extended (~2 weeks long) summer sessions (at DARPA) will focus on connecting performers TAs; develop the TA2 use cases; and familiarize the validation team with performers.
  - Teams should budget to send appropriate representatives.



Open Source and DARPA Open Catalogue

- The program will emphasize creating and leveraging open source technology and architecture. Intellectual property rights and software licenses asserted by proposers are strongly encouraged to be aligned with open source regimes.

- DARPA Open Catalogue Initiative.
  - Publications made available to general public.
  - Software made available via repositories (GitHub, etc.).
  - http://www.darpa.mil/opencatalog/

Proposal Guidelines

- Submit an Abstract first.
  - Abstracts <u>need not</u> reflect the teaming structure of the full proposal.
- A good abstract/proposal:
  - Clearly describes the technical approach.
  - Describes what is different about the approach compared to SOA.
  - Convincingly illustrates how the proposed approach will achieve the program goals.
  - Articulates how TA1/TA2 components would connect.
    - Emphasizes modularity / extensibility.
- If proposing a single TA, describe how your efforts could be validated by a complimentary TA.
  - If possible, describe notional use case (TA1) / representation (TA2).

Proposal Guidelines, TA-specific

TA1:

- Describe the proposed representation.
  - What is powerful about it? What are key innovations?
  - How has it been used for knowledge representation?
  - What extensions will you need to make to apply to the program targets?
  - What kinds of data / knowledge is it suitable for?
  - What kinds of problems does it enable to be solved?
- Describe the proposed analytic methods.
  - How is information added to / recalled from the knowledge representation?
  - What types of analysis / inference can be performed?

TA2:

- Present clear and compelling use cases in a complex system.
  - Statement of the problem, its importance, why it is challenging.
- Describe relevant data and domain knowledge available.
  - Including the structures the TA1 framework would need to capture.
- Identify the target problems / questions to be answered.
  - Including the kinds of analysis / inference the TA1 framework would need to support.

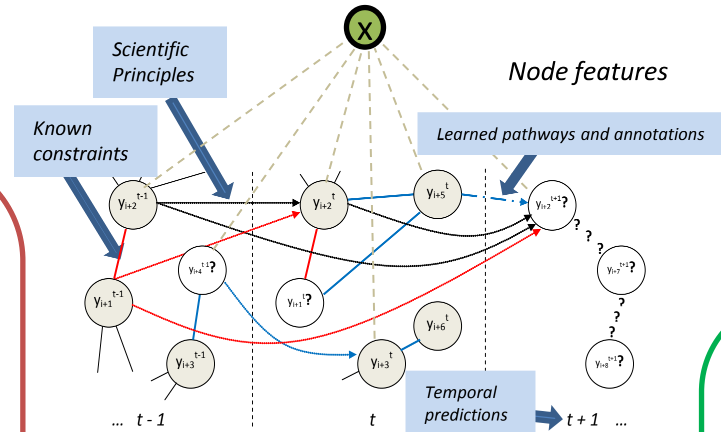
Domain Examples (NOT exhaustive)

- Materials Science.
- Neuroscience.
- Climate Science.
- Autonomous Systems.
- Complex cyber-physical systems such as wireless communications system and smart power grids.
- Gene-protein-disease network.
- Any others that support suitable Use Cases (see the BAA).

Example Enablers and Opportunities

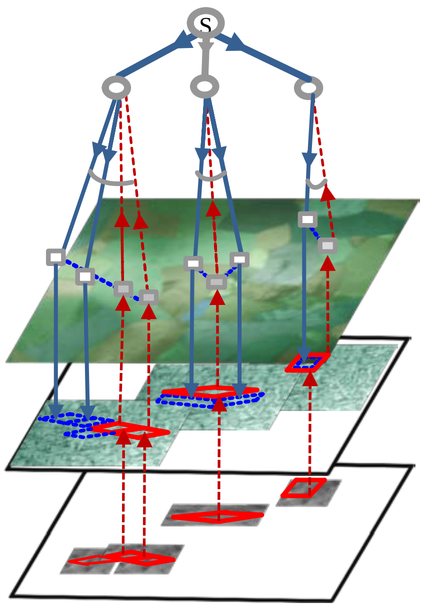
MATHEMATICAL ENABLERS

Extended Graph data-structure



- Graph-based domain knowledge representation.
- Statistical graph processing at scale.
- Link prediction.

Multi-scale analysis



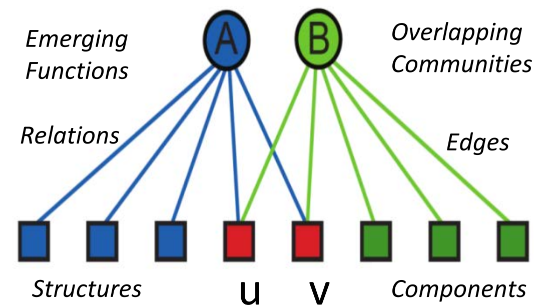
- Space-time-causal representation.
- Cross-scale modeling.
- Top-down / Bottom-up computation
- Semantic detection.

Common operating picture

Knowledge representation and discovery tools

Unified Representation

Large scale model-based data-driven discovery algorithms



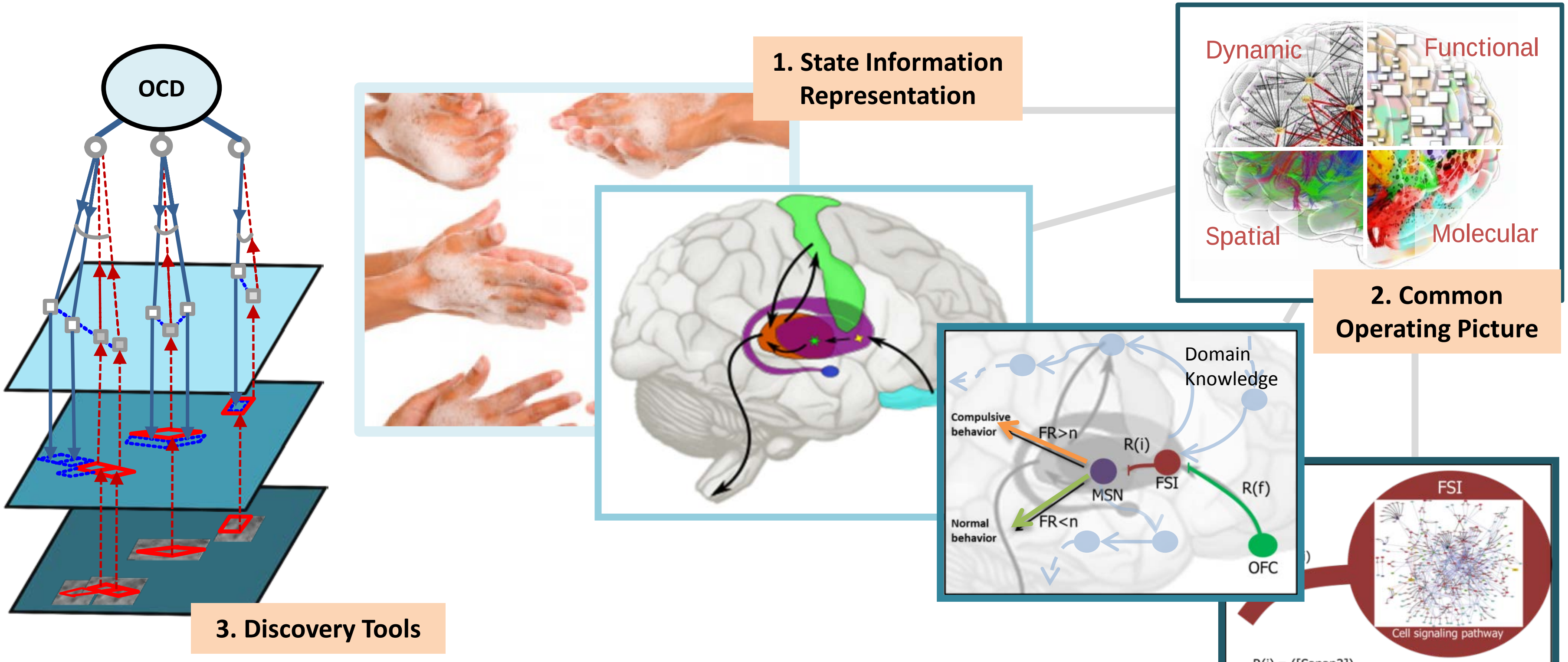
- Detecting mix of overlapping layered communities and functions.

Discovery Tools

SCIENTIFIC OPPORTUNITIES

Neuroscience Example: Deep Dynamics

Control of Obsessive Compulsive Disorder (OCD)

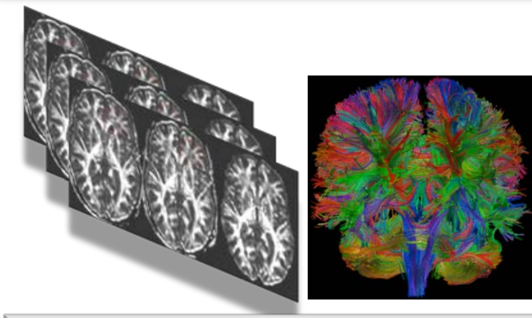


Example impact to scientific research using SIMPLEX technology:

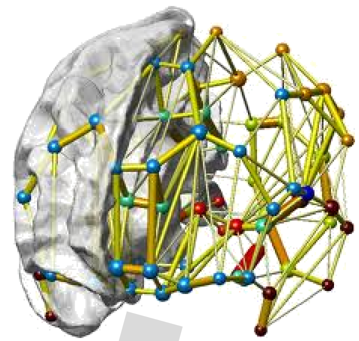
Biological question	Mathematical approach
What are the commonalities between disorders? e.g. OCD and PTSD (space/time across scales)	Community Detection, … ?
Is PTSD affected by MSN type cell activity?	Dynamic, … ?
How would drug treatments that target OFC cells affect OCD and PTSD behavior?	Sensitivity analysis, … ?
How would treatments tested in rodents effect human OCD behavior?	Homologies, Matching, … ?

Example Discovery Tools Use Case:
Statistical Graph Matching for Real-time Brain Network Analysis

Understanding similarity and related pathology can be posed as statistical graph problems, which are computationally intensive on large networks.



Structural (DTI/BMI) and functional (fMRI) data acquired from an individual

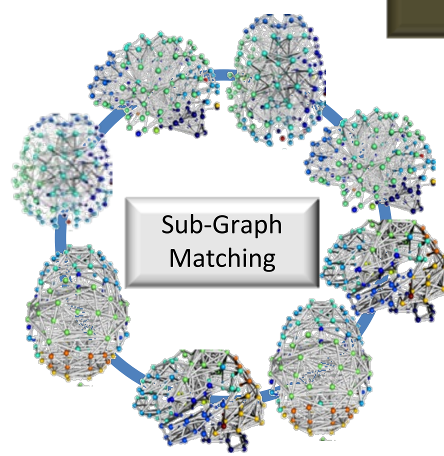


Registered graph abstracted from data

How similar is this graph to normal reference model or to any known pathology class?

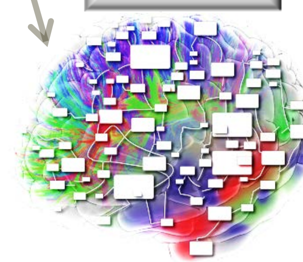
Matching and Clustering

Graph algorithms determine statistical metrics for functional (EEG, BMI, fMRI) and structural (MRI) similarities and can detect normal and abnormal patterns in different parts of the brain network.



Sub-Graph Matching

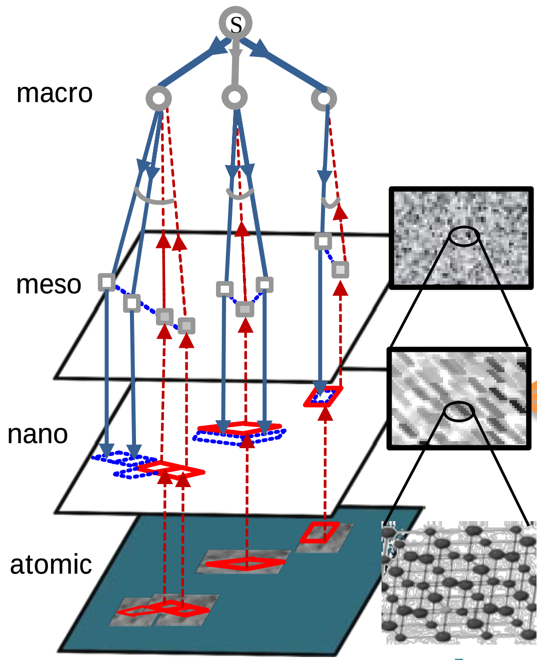
Knowledge Framework

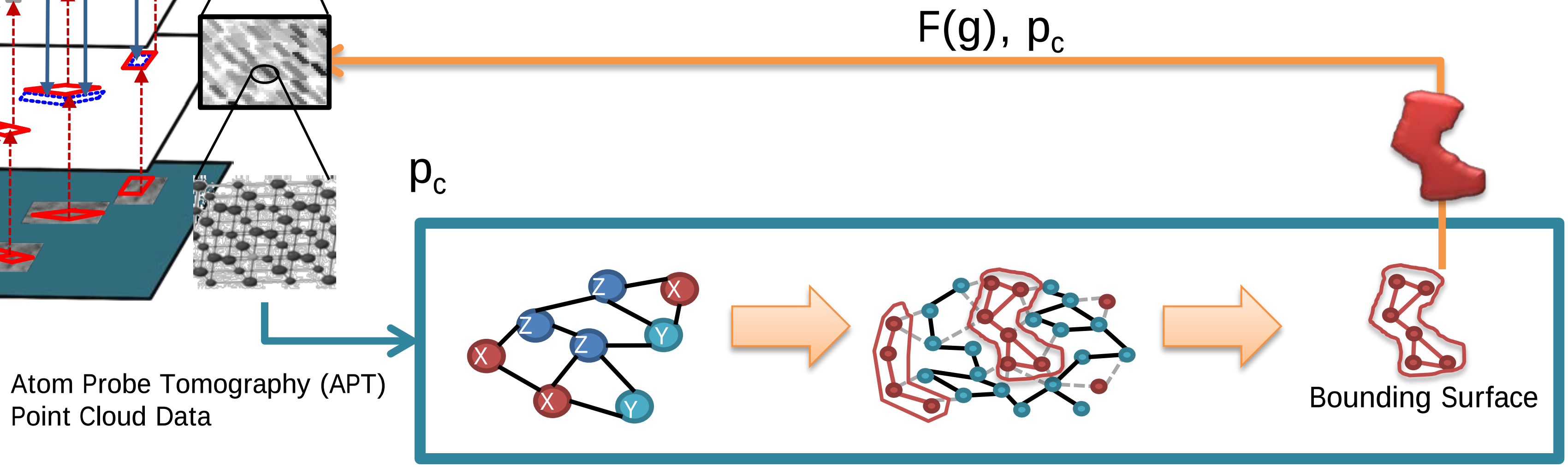


Assembled brain graphs from a population allows statistical analysis of patterns against pathologies.

Materials Science Example:
Framework for discovery of new material

Example: Nano-scale structure from atom-scale features
(Precipitate nano-clusters in alloy)





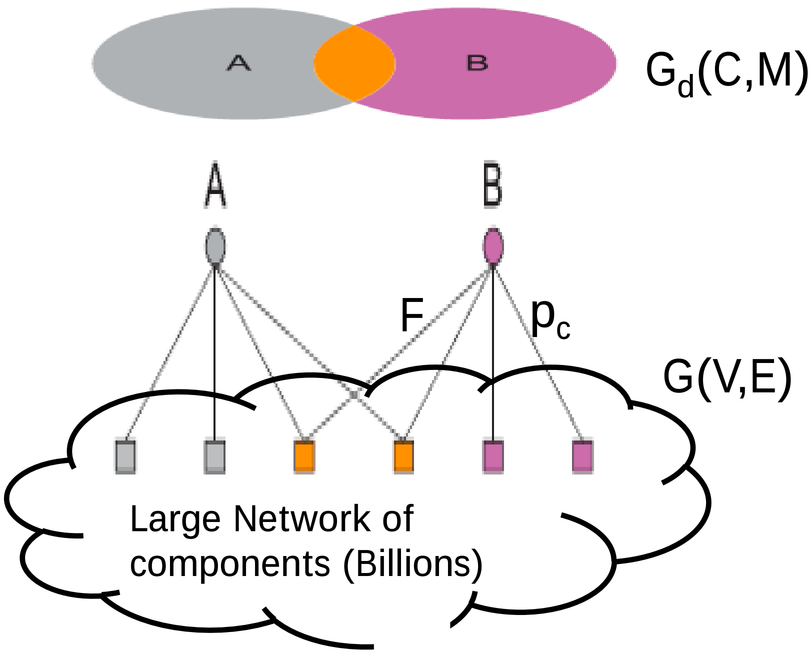
Mathematical Representation
- Nodes = Atoms, labeled by elements.
- Edges = neighbor relations, weighted by spatial distance.

Mathematical Operations
- Graph cut connections between precipitate and solute (clustering).
- Identify precipitate connected components as sub-graphs.

Result:
- Reconstructed precipitate cluster boundary.
- Model interrelation to larger length scales.

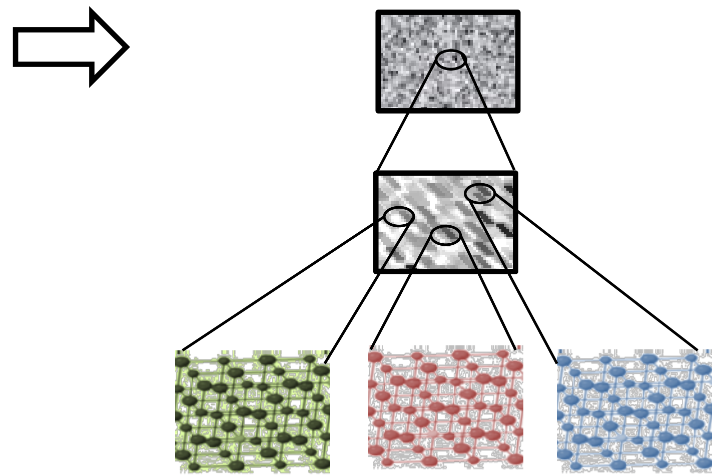
Example – From social network analysis to scientific networks discovery

Today: Identify meso-scale structure of networks (size: Millions and thousands)



Meso-scale properties of materials

Property-driven Dimensionality Reduction
Principle Functional Analysis



Example Methods:

- Community Detection.
- Link Prediction.
- Graph Matching.

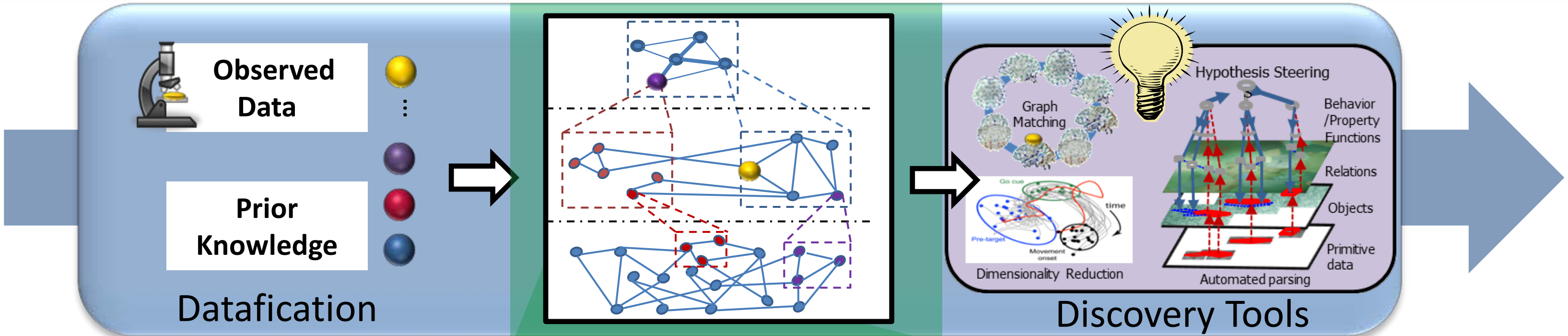
Examples:

- Property-driven Dimensionality Reduction.
- Functional and structural Inference.
- Statistical common reference (COP).

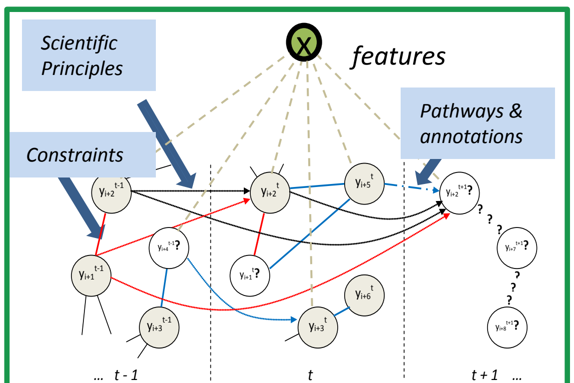
Backups

Area 1: Knowledge Representation

Develop unified knowledge representation framework that enables large scale analysis and discovery methods.



Knowledge Representation



Representation framework

Mathematical formalism
(Methods, Modeling Tools)
Capability: representation-centric model of heterogeneous knowledge across spatial, temporal, and causal scales and modalities.

Computing Foundation
(Methods and Algorithms)
Capability: Statistical Analysis Methods.

Knowledge input/output

Automated learning and embedding
(Computational tools)

Query and Recall
(Computational tools)

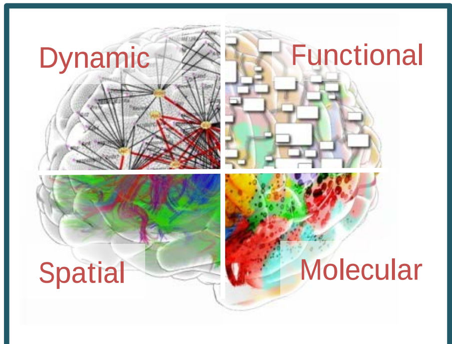
Compact Representation

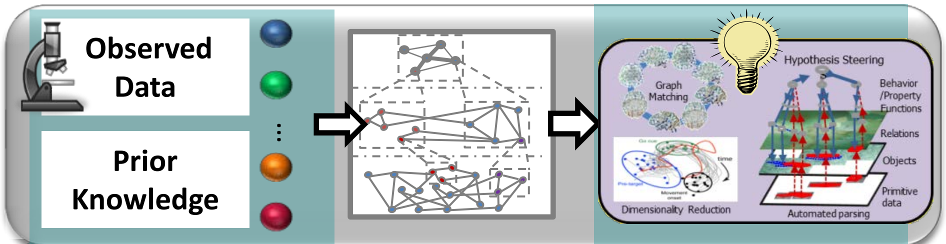
Inverse representation
(Design Methods)
Capability: hypothesis steering.

Iterative algorithms
(Computational tools)
Capability: increase depth and accuracy over time.

Area 2: Datafication & Discovery

Develop tools for domain-specific analytics and discovery methods, and demonstrate quantifiable results in science and engineering domains.





Datafication

Discovery Tools

Domain-specific data ingestion
(Computational tools)

Integration of domain-specific data into knowledge representation
(Methods & Computational tools)

- **Example: Statistical Brain Reference Architecture**
- **Example: Cross-scale modeling and inversion (two scales/properties)**

Potential Target: 100x improvement in data registration accuracy and prediction quality for select modalities.

Data ingestion and standardization tools

Model-driven algorithms
(Computational tools)

Capability: functional inference and big-hypothesis testing.

Novel analytics
(Computational tools)

Capability: fast analysis of large datasets, in-line filtering, principal functional analysis .
Potential Target: 10x-1000x improvement in speed.

Domain-specific discovery tools